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A MAC PROTOCOL FOR UWB HETEROGENEOUS MOBILE AD HOC NETWORKS BASED ON ER BY USING DIRECTIONAL ANTENNA

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ABSTRACT

Ultra-wideband (UWB) communication is a promising enabling technology for future broadband wireless services. A simple, scalable, distributed, efficient medium access control (MAC) protocol is of critical importance to utilize the large bandwidth UWB channels and enable numerous new applications and services cost-effectively. By investigating the characteristics of UWB communications, this paper proposes to use an approach of the DEX Protocol with DU-MAC protocol. For the exclusive regions (ER) calculation, this paper uses a blind discovery mechanism. By combination of these techniques, this paper finds a good solution for MAC protocol that has a low access delay. DEX Protocol has good performance on throughput and energy consumption. DEX protocol uses RTS and CTS frames and two protocols. A TXOP protocol is used for enhancement of the service. Extensive simulation results demonstrate the efficiency and effectiveness of the DEX protocol. This paper has shorter access delays of neighboring users because of shorter time 'T' to transmit data/ACK. The proposed technique in this paper is able to consider node mobility. It has also shorter access delays of neighboring users because of shorter time 'T' to transmit data/ACK. In this paper, the value of the path loss exponent is accurately measured or estimated, so the value of D may not be optimal and paper, it needs to reduce the power consumption.

KEYWORDS: MANET, DEX Protocol, DU MAC Protocol, Beam Caching, Data Transmission

1. INTRODUCTION

UWB Ad Hoc Networks

Ultra Wide Band (UWB) is a new wireless short-range technology [1]. Ultra-wideband (UWB) wireless communication is a hopeful spread-spectrum technology, which is able to support very high data rates and affords specific position information of mobile users. It has numerous tempting key features like very high data rates, low-power consumption, coexistence with other technologies in the equivalent bandwidth and precise location determination [2]. An UWB system is distinct as a radio system that has a 10-dB bandwidth that is either larger than 20% of its center frequency or absorbs 500 MHz or more [3]. In ad hoc networks, nodes are linked by means of wireless links that are established and used impulsively without relying on a pre-existing infrastructure [3].

MAC Protocol in UWB Ad Hoc Networks

In a wireless network, MAC protocol provides channel access and Quality of Service (QoS). The MAC protocol manages the control of multiple user channel access in a protected mode in the company of quality of service guarantees.

This functionality has to be achieved with negligible overhead in terms of power, latency and bandwidth [4]. IEEE 802.11 specifies two medium access control protocols that are 1. Point Coordination Function (PCF) and 2. Distributed Coordination Function (DCF). Point Coordination Function is a centralized scheme, while the Distributed Coordination Function is a totally distributed scheme [5]. Some protocols are Extreme Spectrum, Inc. it determined to map its UWB technology onto the emerging IEEE 802.15.3, WI Media a high-rate wireless Personal Area Network (PAN) technology. Pulse Link, Inc. has studied 802.11, 802.15.3 and Hyperlink [7].

Issues of MAC Protocol Design in UWB Ad Hoc Network

Wireless has limited channel bandwidth that is normally very less than wired networks and the wireless medium is intrinsically error prone. Since MANET has frequent mobility and time varying channel, the MAC protocol design should consider these issues also [6]. In UWB, channel acquisition time is is quite high with order of a few milliseconds [7]. There are also some issues of MAC in UWB which are discussed below

QoS Management at the MAC Layer

A modern data network must be able to convey at the same time data, voice, multi-media (e.g. streaming video), and real-time-critical traffic by acclimatizing its behavior to various user necessities and traffic characteristics. QoS describes the presentation that ought to assured by the network to meet user expectations. From admission control and packet scheduling, to power control and MAC organization, QoS management entails numerous MAC functions. So QoS management at the MAC Layer is a main issue.

Medium Sharing

Most of the presented MAC protocols for distributed networks are based on the key theory that users split a single channel by using key. This involves that the resource is to be shared to the radio access itself from a resource sharing point of view.

MAC Organization

The MAC organization plays vital role in the design of a particular MAC for UWB networks. The acceptance of a Domain based structure is a potential solution because it addresses management of multiple Time Hopping codes. Alternatively, a multiple channel MAC could considerably boost network throughput by utilizing the intrinsic multiple channel UWB capability.

Admission Control

Admission control is requisite when overcrowding must be evaded for getting network performance necessities. Admission control is compulsory in QoS-aware networks in which unregulated access might simply provoke contravention of performance guarantees. It is characteristically implemented with centralized schemes.

Packet Scheduling

The packet scheduling algorithm decides the order in which buffered packets are elected for transmission. Efficient packet scheduling in wireless networks cannot disregard the status of the wireless channel.

Power Control

Since in wireless networks the nodes are battery powered so they have a limited source of energy. Power control leads to optimization of emitted power levels and having three attractive effects. By minimizing power consumption, we can get longer autonomy, reduction of interference and adaptation of emitted power to link variation due to channel modifications and mobility. So power control is a big issue [8].

In DEX Protocol [12] there is a need of effective mechanism that can calculate ER effectively for providing a good MAC Protocol. To overcome the limitation, this is paper gives a combination of the two protocols DEX protocol and DU MAC protocol in two phases and an overall algorithm for the proposed methodology. The proposed methodology is briefly defined in section three.

To perform the research work, in a well-structured manner this paper gives a suitable introduction with problems in introduction part that is described in section one. The work is strengthened, verified and the motto is derived from the literature works that is given in section two. Then paper enters in to the real problem definition and a structured solution in section three. The last section carries a suitable conclusion with the advantages and overall work.

2. LITERATURE REVIEW

E. Karapistoli *et al.* [10] have discussed about MAC protocol for low-rate UWB wireless sensor networks. In this paper directional antennas are used. The authors proposed a novel MAC protocol specifically designed for the energy-constrained WSNs. This protocol expands the performance of the IEEE 802.15.4a standard by employing directional antennas. It is a dispersed random access MAC protocol with devoted procedures for power efficient Omni-directional communications. The performance metrics like delay overhead, Packet delivery ratio, Average transmission cost and Average MAC delay has been discussed in this paper. The node mobility is not considered in simulation scenarios, so it needs to consider node mobility in simulation.

L. X. Cai *et al*. [11] have discussed about the efficiency of MAC protocol in the Ultra Wideband Network. The authors proposed ER-based approach in the MAC protocol design for both centralized and distributed multi hop UWB networks. By using the concept of ER and considering the salient features of UWB communications the potential multi-user interference is properly managed. This protocol can efficiently exploit the spatial multiplexing gain and advance the network performance**.** This protocol uses larger time 'T' to transmit data/ACK, this may cause longer access delays of neighboring users.

L. X. Cai *et al* [12] have discussed about the designing and optimization of a MAC Protocol for Multi-Hop Ultra-Wideband Networks. The authors have proposed a distributed MAC protocol named DEX protocol, for multi-hop UWB networks. DEX protocol centralized on the spatial multiplexing gain of UWB networks by preserving exclusive regions (ER) surrounding the sender and receiver for data and acknowledgment (ACK) transmissions. So that users able to share network resources efficiently and fairly in a distributed and asynchronous manner. The performance metrics like throughput, fairness, and access delay have been discussed in this paper. In this protocol the expected network transport throughput can maximize by finding the optimal value of distance ‘D’, Distance is a function of path loss exponent 'α', but in practical the value of α may not be accurately measured or estimated, so the value of D may not be optimal.

J. Zhou *et al.* [13] have discussed about MAC Protocol for QoS provided UWB Ad Hoc Network. They have proposed a MAC protocol for UWB MANET which provides QoS services for real-time application. The unique characteristics of UWB are utilized while considering the QoS requirements. Performance metrics like throughput, end to end delay, power consumption and power utilization have been discussed in this paper. The power consumption of this protocol is 5% higher than the PC Protocol so it needs to reduce the power consumption of this paper.

3. PROPOSED SOLUTION

Overview and Architecture

In the literature revive this paper have discussed some papers related to MAC Design Protocol in UWB Ad Hoc network. In the paper [10] the authors didn't consider node mobility. Paper [11] has longer access delays of neighboring users because of larger time 'T' to transmit data/ACK. Paper [12] the value of the path loss exponent 'α' may not be accurately measured or estimated, so the value of D may not be optimal and paper [13] it needs to reduce the power consumption. From literature review this paper analyzed that in DEX Protocol [12] there is a need of effective mechanism that can calculate ER effectively for providing a good MAC Protocol.

To give a solution in structured manner the paper first gives an architectural diagram of MANET and the proposed method.

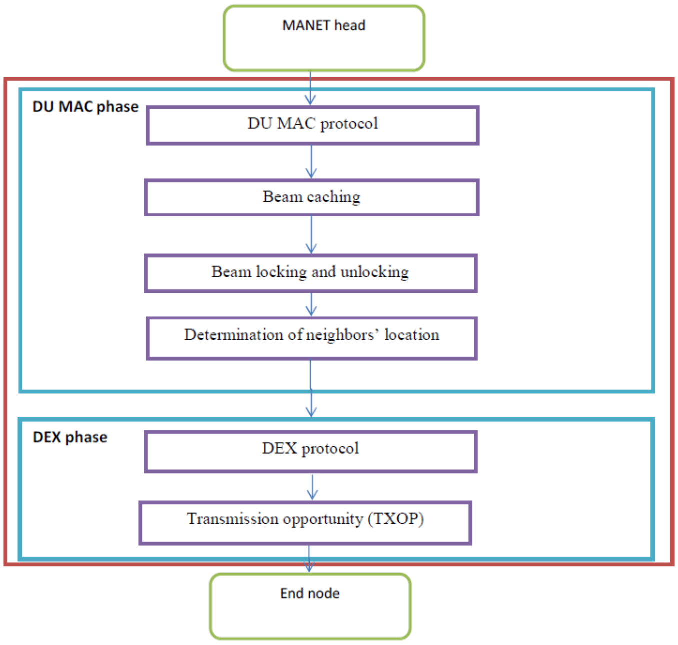

Figure 1: Architecture Diagram

This paper proposes to design a new MAC protocol for the UWB heterogeneous MANETs. It considers a mobile ad hoc network of nodes with heterogeneous power levels for transmission. Each individual device is assumed to have a constant transmit power, which may be different for different devices in the network.

For solution, this paper uses a combined approach of the DEX Protocol with DU-MAC protocol. For ER calculation, this paper uses a blind discovery mechanism. By combination of these protocols this paper will find a good

solution for MAC protocol that has a low access delay. DEX Protocol has good performance on throughput and energy consumption.

Figure 1 shows the architectural diagram of our proposed method. The protocols have to be built in the communication between MANET head and end node. There are six steps present in the whole procedure. The six steps are DU MAC protocol, Beam caching, Beam locking and unlocking, Determination of neighbors' location, Information of blind discovery mechanism, Transmission opportunity (TXOP).

The figure below shows system design of the MANET. In MANET the whole area of the network is divided into some cells. The cells are of hexagonal configuration. Each cell has its cell head. There are a number of service users present who are getting service from the cell head. Service users are movable in nature. Each has cell some directional antennas to provide uninterrupted service.

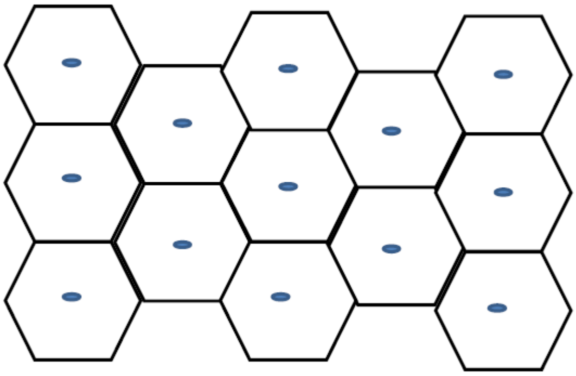

Figure 2: System Design

The diagram below shows a single cell structure of the MANET. The cell has a cell head at the center. The cell head is working as a service provider. It has six directional antennas. The figure below clearly shows the directional view of cells.

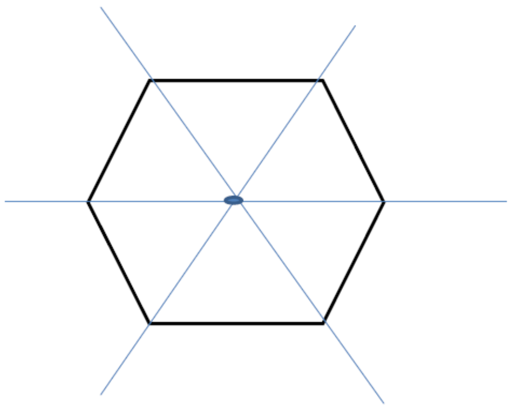

Figure 3: Omni Directional Antenna in the Single Cell of MANET

3.2 Determination of Exclusive Region (ER) Using DU-MAC Protocol

In DU-MAC protocol, Exclusive Region (ER) does not refer to the exact physical location of the nodes. It refers to the sector where the neighbor of the node exists.

When a node want to transmit its neighbor, ER is used to beam form its antenna to the respective sector. This can be done by using a directional blind discovery protocol.

Directional Blind Discovery Protocol

Directional Blind Discovery Protocol depends on the discovery strategy supported by 802.15.4a standard. This standard is applied to each antenna beam. Beam caching refers to the process of a node storing beam-related information after the detection of a preamble trailer. Nodes begin to look for neighbours through active channel scanning in a nonbeacon-enabled 802.15.4a network. The steps involved in this protocol are as follows:

Step 1: When a node wants to transmit the data, it will check whether the neighbour information is stored. If it has, the node will begin to transmit. Otherwise, it will initiate the blind discovery process.

Step 2: Each node send a SCAN request that initiates a channel scan and searches for activity within the Personal Operating Space (POS) of the scanning device.

Step 3: For the UWB PHY, the preamble code related to the specified channel is scanned. The preamble code sequences range from PC_1 to PC_8 whose length is 31. Each UWB channel must use two codes during discovery and transmission.

Step 4: Node transmits a preamble trailer from the first antenna sector using the preamble code related to the UWB channel.

Step 5: After the reception of preamble trailer, the neighbours perform beam caching. Then, all the neighbours respond by sending the HELLO packets to the node as a neighbour table announcement. HELLO packet has their cached beam information. Each neighbour node uses a random delay to transmit the HELLO packet. This is performed to avoid systematic collision.

Step 6: On receiving the response, neighbour node records the information in the HELLO packet and forms a neighbour table.

Step 7: Then, the neighbour locks its beam pattern for the data reception towards the direction of the received power. The beam patterns at both sides are used for both transmission and reception, and are unlocked after the ACK frame transmission is completed. This process is called as beam locking and unlocking.

Step 8: The node switches to the subsequent beam and repeats the above steps until the 360° azimuthal plane is covered for identifying the ER of the neighbor nodes.

If there is no HELLO packet received, node concludes that there is no neighbors in the sector. Then, the sweeping mechanism ignores the sector with no neighbours. Blind Discovery process runs either reactively or periodically, as the neighbor node that is involved in discovering their neighbors are not detected.

Distributed Exclusive Region (DEX) Protocol

Distributed Exclusive Region (DER) protocol reserves the ER surrounding the sender and receiver for data and acknowledgment (ACK) transmissions in UWB networks. This is performed to efficiently and fairly share network resources in a distributed and asynchronous manner. All nodes in the network share the spreading codes. Among them, one common spreading code is selected to transmit control messages such as RTS and CTS frames. Each node maintains a

code table that has the spreading codes required for the ongoing neighboring transmissions. The procedures involved in selecting the code and initiating the transmission at the sender and receiver side is briefly discussed below:

Sender

Each node maintains a code table and a Network Allocation Vector (NAV). The algorithm involved in the DEX protocol at the sender side is as follows:

Assumptions

- The initial contention window size equals the minimum window size, i.e., CW = CW min
- The node sets its retry counter to 0.

Step 1: When node i receives the data from the upper layer for transmission to node j, i will estimate the spreading code using hash function for the transmission. The spreading code S is given by,

$$S = \text{Hash}\ (Mi + Mj) \tag{1}$$

Where Mi and Mj denotes the MAC addresses of i and j, respectively.

Step 2: If the value of NAV is not equal to zero, node i will wait until it becomes zero. Otherwise, node i initiates the channel sensing process.

Step 3: If the channel is sensed to be idle for a Backoff Inter Frame Space (BIFS), node i transmits an RTS frame to node j. RTS frame contains the spreading code S and the transmission time.

The transmission time is calculated by,

$$TT_2 = RTS + SIFS + CTS + SIFS + DATA + ACK \tag{2}$$

Otherwise, node i enters an exponential random backoff procedure and sets a Backoff Counter (BC) uniformly distributed over [0, *CW*) for the initial transmission attempt.

Step 4: When the BC is zero, then node i will freeze the *BC* until the channel becomes idle. When BC is greater than zero, the channel sensing process will be initiated again. If the channel is idle, BC will be decreased by 1 for each idle slot.

Step 5: If the channel is busy and node i did not receive an RTS/CTS, node i must continue the channel sensing until the channel becomes idle for *BIFS* duration. If node i overhears an RTS/CTS frame from another transmission t_2, it will check whether the sender is within the ER range or not.

Step 6: If either the transmitter or the receiver of t_2 is inside i's ER region, node i will postpone its current transmission t_1 until the t_2 completes and set its NAV based on transmission time TT_2. If node i is located outside the ER of t_2, node i will wait until RTS times out and set NAV based on TT_1.

The transmission time TT_1 is calculated by,

$$T1 = RTS + SIFS + CTS. \tag{3}$$

Step 7: Node i updates the code table by adding the information about the new transmission. If there is any conflict occurs in the table, the spreading code S is calculated by,

$$S = Hash (Mi + S) \quad (4)$$

Step 8: Node i wait until NAV is equal to zero. Then, node i transmit the RTS frame to node j.

Step 9: If the node i receives CTS frame from node j before timeout, then the node i will transmit the data at rate R after Short Inter Frame Space (SIFS).

Step 10: If node i receives CTS frame from node j, retry counter value is increased by 1. If retry counter value is greater than retransmission limit, then node i will drop the current frame and repeat the entire process.

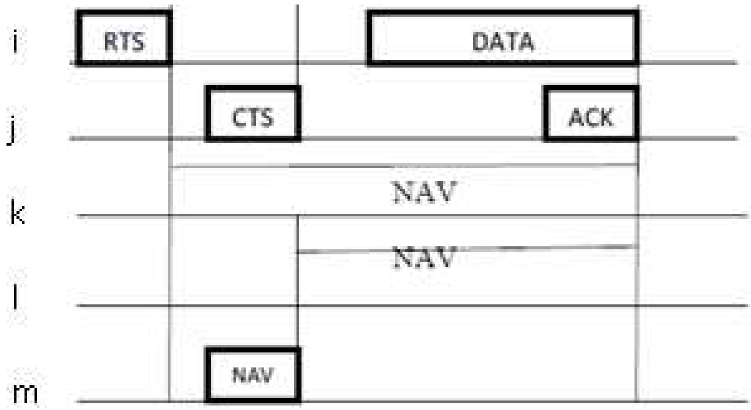

Figure 4: Showing Network Allocation Vector Update

Figure 4 Shows the NAV process where i and j exchange RTS and CTS. k and l are neighbors within the ER of flow i and j, respectively, and m is another neighbor outside the ER of flow ij. Here, node i sends the RTS frame to node j. Node j respond by sending CTS frame. Then, node i send the data. After receiving the data, node j sends an ACK message.

Receiver

The procedure performed at the receiver side is as follows:

Step 1: If NAV is not equal to zero, node will wait till the NAV becomes zero. Otherwise, node becomes ready for receiving the data or control messages.

Step 2: When the node j overhears the RTS/CTS, then the node j checks whether the overheard transmitter is in its ER or not.

Step 3: If the overheard transmitter is in j's ER, then j will update the code table and set NAV based on TT_1. Otherwise, j will set NAV based on TT_2.

Step 4: If node j receive RTS from node i, the following conditions are checked:

- S should not conflict with any record in j's code table,
- Channel must be idle

Step 5: If the conditions are satisfied, node j transmits the CTS message to node i. Then, node j receives the data from node i and sends ACK to node i. Otherwise, repeat the entire process.

Transmission Opportunity (TXOP)

Transmission Opportunity (TXOP) is used to increase the efficiency of the DEX protocol. In each RTS/CTS, time duration *T* is reserved. A transmitter can transmit a burst of data frames during *T*.

When T is large, then resource will be efficiently utilized as the less overhead is involved in each transmission. However, this may lead to a larger access delay. Hence, T must be selected so that the access delay is tolerable for other flows in the ER region. A smaller ER region allows for more concurrent transmissions that decreases the access delay of each flow.

The value of T must be large for DEX while maintaining the desired delay and fairness performance.

4. SIMULATION RESULTS

Simulation Model and Parameters

The Network Simulator (NS2) [14], is used to simulate the proposed architecture. In the simulation, the mobile nodes move in a 1250 meter x 1250 meter region for 50 seconds of simulation time. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR).

The simulation settings and parameters are summarized in table.

Table 1

No. of Nodes	30,50,70,90 and 110
Area Size	1250 X 1250
Mac	IF Control
Transmission Range	250m
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512
Initial Energy	10.1J
Transmission Power	0.660
Receiving Power	0.395
Rate	100, 200, 300, 400 and 500Kb

Performance Metrics

The proposed MAC for UWB Heterogeneous Mobile Ad Hoc Networks Based on ER by using Directional Antenna is compared with the DUMAC technique [10]. The performance is evaluated mainly, according to the following metrics.

- **Packet Delivery Ratio:** It is the ratio between the number of packets received and the number of packets sent.
- **Packet Drop**: It refers the average number of packets dropped during the transmission
- **Energy Consumption:** It is the amount of energy consumed by the nodes to transmit the data packets to the receiver.
- **Delay:** It is the amount of time taken by the nodes to transmit the data packets.

RESULTS

Based on Nodes

In our first experiment we vary the number of nodes as 30, 50, 70, 90 and 110.

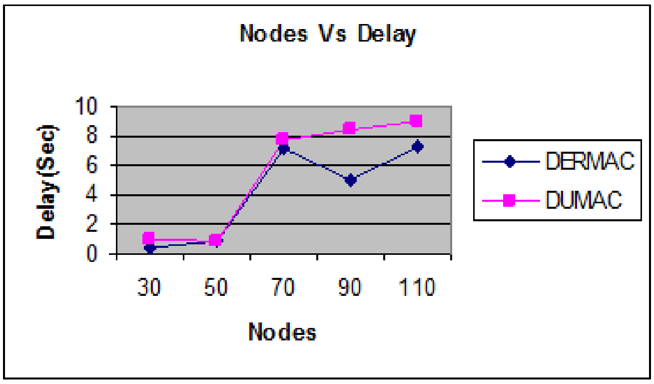

Figure 5: Nodes vs Delay

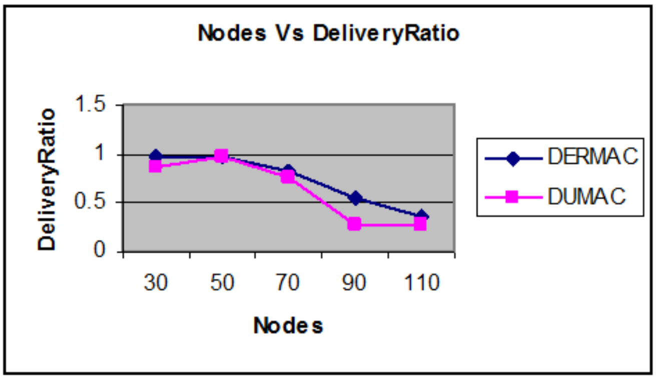

Figure 6: Nodes vs Delivery Ratio

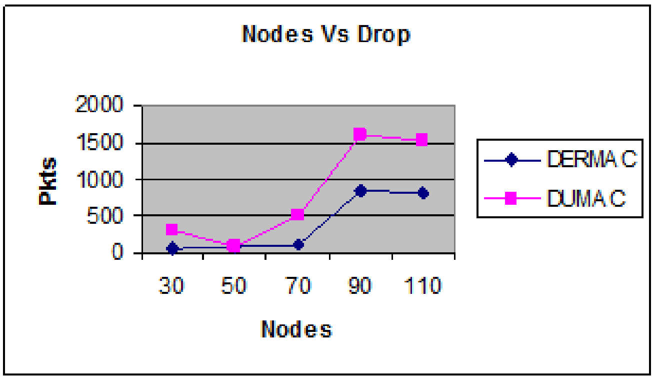

Figure 7: Nodes vs Drop

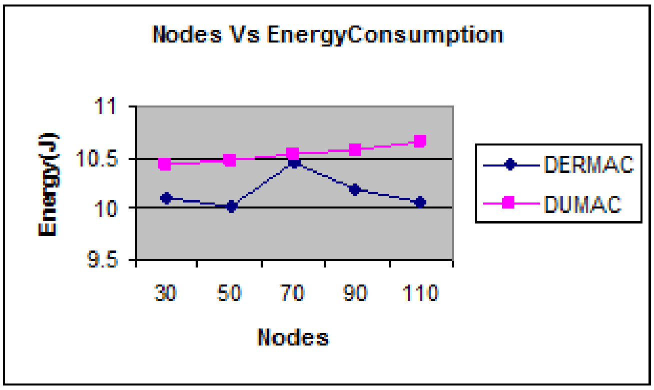

Figure 8: Nodes vs Energy Consumption

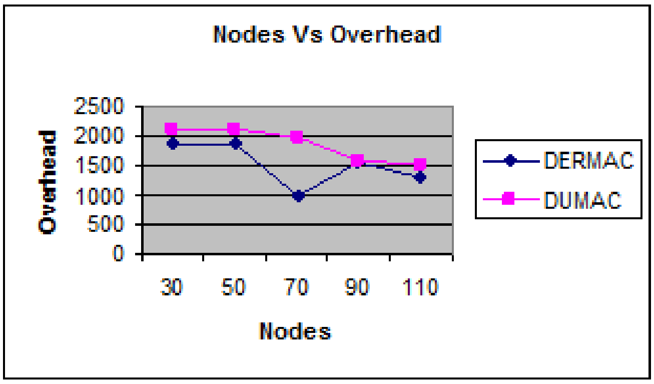

Figure 9: Nodes vs Overhead

Figure 5 shows the delay of DERMAC and DUMAC techniques for different number of nodes scenario. We can conclude that the delay of our proposed DERMAC approach has 25% of less than DUMAC approach.

Figure 6 shows the delivery ratio of DERMAC and DUMAC techniques for different number of nodes scenario. We can conclude that the delivery ratio of our proposed DERMAC approach has 19% of higher than DUMAC approach.

Figure 7 shows the drop of DERMAC and DUMAC techniques for different number of nodes scenario. We can conclude that the drop of our proposed DERMAC approach has 51% of less than DUMAC approach.

Figure 8 shows the energy consumption of DERMAC and DUMAC techniques for different number of nodes scenario. We can conclude that the energy consumption of our proposed DERMAC approach has 4% of less than DUMAC approach.

Figure 9 shows the overhead of DERMAC and DUMAC techniques for different number of nodes scenario. We can conclude that the overhead of our proposed DERMAC approach has 18% of less than DUMAC approach.

Based on Rate

In our second experiment we vary the transmission rate as 100,200,300,400 and 500Kb.

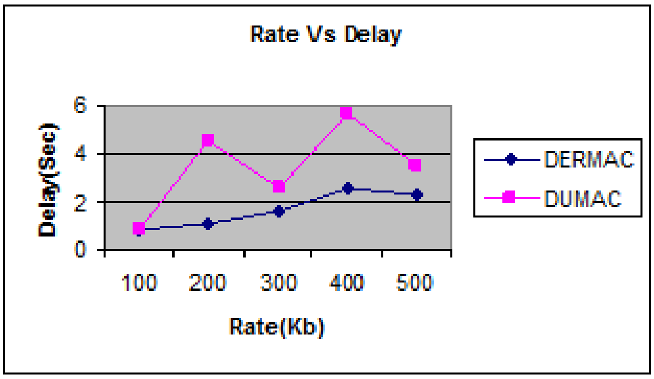

Figure 10: Rate vs Delay

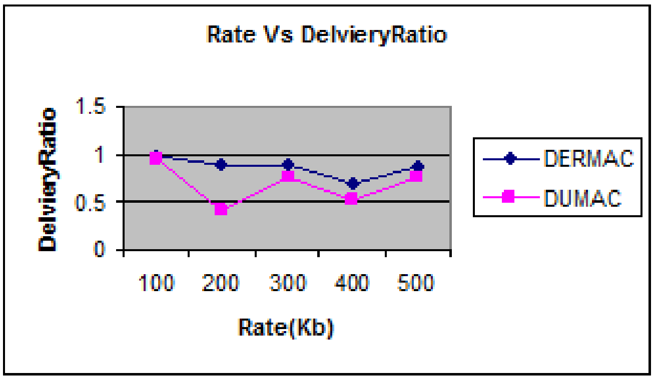

Figure 11: Rate vs Delivery Ratio

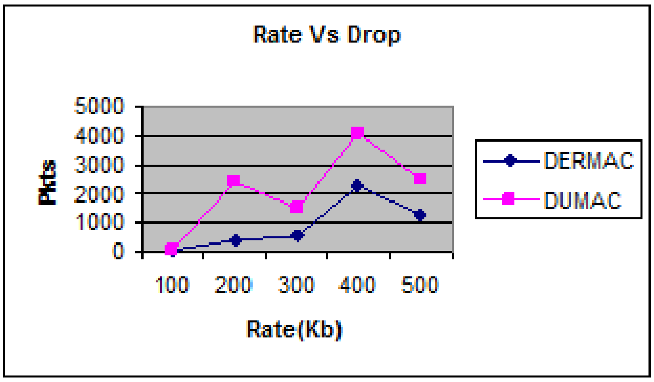

Figure 12: Rate vs Drop

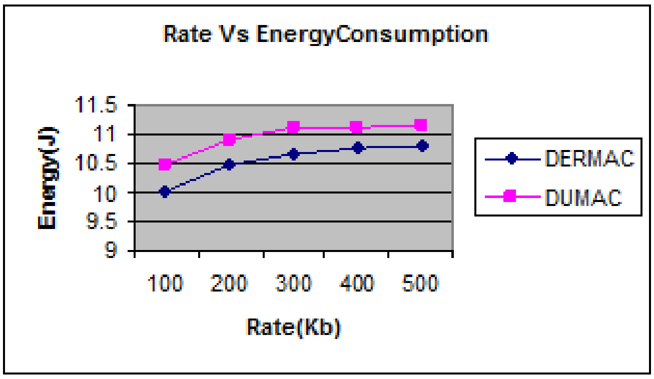

Figure 13: Rate vs Energy Consumption

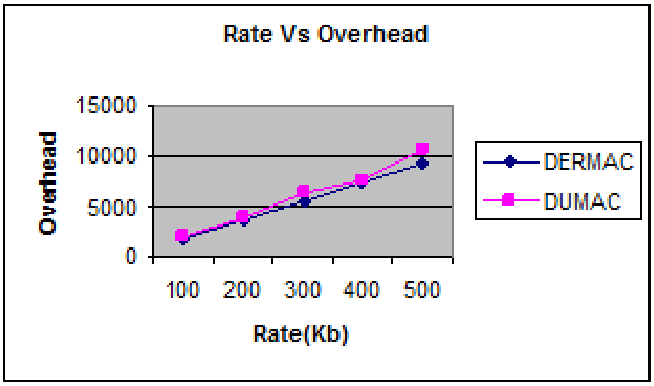

Figure 14: Rate vs Overhead

Figure 10 shows the delay of DERMAC and DUMAC techniques for different rate scenario. We can conclude that the delay of our proposed DERMAC approach has 41% of less than DUMAC approach.

Figure 11 shows the delivery ratio of DERMAC and DUMAC techniques for different rate scenario. We can conclude that the delivery ratio of our proposed DERMAC approach has 21% of higher than DUMAC approach.

Figure 12 shows the drop of DERMAC and DUMAC techniques for different rate scenario. We can conclude that the drop of our proposed DERMAC approach has 48% of less than DUMAC approach.

Figure 13 shows the energy consumption of DERMAC and DUMAC techniques for different rate scenario. We can conclude that the energy consumption of our proposed DERMAC approach has 4% of less than DUMAC approach.

Figure 14 shows the overhead of DERMAC and DUMAC techniques for different rate scenario. We can conclude that the overhead of our proposed DERMAC approach has 8% of less than DUMAC approach.

5. CONCLUSIONS

For solution this paper uses a combine approach of the DEX Protocol with DU-MAC protocol. For the ER calculation of this paper uses a blind discovery mechanism. By combination of these protocols this paper will find a good solution for MAC protocol that has a low access delay. DEX Protocol has good performance on throughput and energy consumption. The paper first gives an architectural diagram of MANET and the proposed method. Then the paper is giving the architecture of the proposed methodology. The two protocols DEX protocol and DU MAC protocol in two phases and an overall algorithm for the proposed methodology.

The proposed technique in this paper is able to consider node mobility. It has also shorter access delays of neighboring users because of shorter time 'T' to transmit data/ACK. In this paper, the value of the path loss exponent is accurately measured or estimated, so the value of D may not be optimal and paper, it needs to reduce the power consumption.

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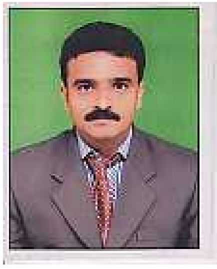

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